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16. ABSTRACT
This paper describes the nature, structure and content of the NATO Committee on the Challenges of Modern Society (CCMS) Pilot Study "Demonstration of Remedial Action Technologies for Contaminated Land and Groundwater" and the associated CCMS Fellowship programme. To date, twelve projects in six countries have been selected for inclusion in the programme which will involve periodic expert review during the five years for which the project will run. The paper draws special attention to: (i) the work on microbial clean up techniques included in the programme, and (ii) the outcome of the first international meeting held in Washington D.C. in 1987.

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NATO/CCMS PILOT STUDY ON DEMONSTRATION OF REMEDIAL ACTION TECHNOLOGIES FOR CONTAMINATED LAND AND GROUNDWATER - 1988 ACTIVITIES

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1. INTRODUCTION

The purpose of the NATO/Committee on the challenges of Modern Society (CCMS) Pilot Study "Demonstration of Remedial Action Technologies for Contaminated Land and Groundwater" is to promote the exchange of information on new and existing technologies for dealing with 'problem' hazardous waste sites. The Pilot Study is based on periodic review by an international group of experts drawn from the participating countries of the results of demonstration projects carried out in a number of the participating countries. The Study, which is planned to last for five years, is "co-piloted" by the Federal Republic of Germany (FRG), and the Netherlands.

This is the second of a series of articles which will publish the progress of the Study on an annual basis. The first article in the series was (1) "NATO/CCMS Pilot Study on Demonstration of Remedial Action Technologies for Contaminated Land and Groundwater."

The Study compliments and enhances programmes to develop, evaluate, and demonstrate clean-up technologies in a number of the participant countries. In particular, the USA (the 'SITE' programme (2)), the Netherlands and the FRG.

2. PROGRESS TO DATE

Representatives of six countries attended the first 'Workshop' held in Karlsruhe, FRG in March 1985 at which time twelve initial projects were selected for inclusion in the Study (3). These projects are listed in Table 1 and described briefly below. As the various projects are completed, furtner projects will be selected for inclusion in the programme. The first full technical meeting at which the progress of the various projects was discussed was held in Washington, DC in November, 1987 (4). A second Workshop will be held in Hamburg, FRG in April, 1988. To date eleven countries (Canada, Denmark, FRG, France, Greece, Italy, Japan, the Netherlands, Norway, Spain, United Kingdom, USA) have associated themselves with the Pilot Study in some way, although only six

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(see Table 1) have involved themselves to the extent of nominating demonstration projects for inclusion in the Study. National contacts are listed in Table 2.

Each year CCMS awards a number of Fellowships for work related to the on-going Pilot Studies. In 1987, six fellowships were awarded for work related to site clean-up.

The activities of these Fellows is ment to augment the primary objectives of the Pilot Study. It is intended that each Fellow will publish the results of his activities on a periodic basis, as data warrents, but not less than once during the life of the project.

3. THE INDIVIDUAL PROJECTS

3.1 Ville Mercier, Canada

The Ville Mercier is located on the south shore of the St. Lawrence river about 20 km southwest of Montreal (5). Groundwater is a major source of potable water for the local population. From 1968 to 1972 some 40,000 m^3 of waste oils and liquid industrial wastes from chemical and petrochemical industries in the Montreal area were dumped into a lagoon in an old gravel pit located in several kilometres southeast of Ville Mercier. In October 1971, it was discovered that several wells in the vicinity were contaminated. The site was closed in 1972, and it was estimated that 20,000 m^3 of wastes remained in the lagoons. Sampling conducted by the Quebec Ministry of the Environment (MENVIQ) revealed the presence of phenols and chlorinated organic compounds in the groundwater in the area.

A program to rehabilitate the aquifer was started by the government of Quebec in 1981. The liquid material which was stored in the lagoon was first removed (incineration, landfill). Following this, MENVIQ awarded contracts to develop a purge-well system and to design and construct a groundwater treatment facility.

The treatment system includes the following elements; air stripping, alum and polymer-activated flocculation-sedimentation, rapid sand filtration and activated carbon adsorption. The sludge is disposed to a landfill. Several problems have been encountered: proliferation of bacteria; plugging of the treatment equipment; loss of activated carbon; and clogging of the wells. The addition of chlorine and peroxide at the head of the treatment system, and of chlorine dioxide before filtration, has solved most of these problems and improved treatment performance. The water treatment objectives have been met, except for 1,2 dichloroethane, which resists treatment because the initial concentration is very high. Afger three years operation and pumping out of 3.6 M m^3 of contaminated groundwater, a substantial abatement in the organic contaminants has been achieved and an acceptable degree of decontamination seems likely to be achieved more rapidly than at first anticipated. It is expected that a further 3.8 M m^3 will be treated during the final two years planned operation of the plant.

3.2 Skrydstrup, Denmark

The Skrydstrup site is a former gravel pit used from 1963-1974 for the disposal of chemical/industrial waste from a refrigertor factory (6). Some of this waste was stored in several hundred drums at the site. There have been extensive chemical, geological and hydrogeological investigations since 1986. Trichloroethane, trichloroethylene, paint and acid wastes have resulted in groundwater pollution. Contaminants include haloalkyl phosphates used as flame retardants in insulating foams. The remedial action consists of digging up, removal and off-site disposal of several hundred drums, followed by groundwater pumping and treating

and on-site aerobic/anaerobic treatment of the polluted soil by a variety of means including microbial treatment. The groundwater system will involve air-stripping and active carbon adsorption over an anticipated 10-15 years from 1988.

Drums and obviously contaminated soil were excavated and removed from the site. Several full scale development projects have been started to deal with the contaminated soil and groundwater;

i) bio-degradation of chlorinated solvents in contaminated soil,
ii) aerobic bio-degradation by addition of natural gas in columns with activated carbon adsorption,
iii) aerobic bio-degradation of chlorinated solvents in the unsaturated zone by co-metabolism by oxidation of methane and/or propane,
iv) anaerobic bio-degradation in the contaminated zone by addition of sodium acetate.

3.3 Charlottenberg, Berlin, FRG

The scrap metal site in the Charlottenberg area of Berlin (7) is contaminated with cyanide, arsenic, cadmium, mercury, PCB, lead, volatile chlorinated hydrocarbons, and oil. Remedial operations have been active since December, 1986 and consist of high pressure soils washing. A Netherlands company, Klockner Oecotec GMHB, has used this high pressure soils washing process to clean 100,000 tonnes of contaminated soils and removed over 95% of the pollutants. High pressure water jets are used to physically strip off hydrocarbons and heavy metal residues from the soils. This process is particularly promising for sandy/gravelly soils but is less effective for clays.

3.4 Unna-Boenen, North Rhine-Westphalia, FRG

The coke oven site at Unna-Boenen, North Rhine-Westphalia is contaminated with aromatic hydrocarbons, tars and acid resins (8). Volatile organic compounds comprise 5% of the waste, by weight. The site is estimated to be 230,000 square meters in area.

A variety of technologies will be applied to the site, individually focused on the soil and aqueous phases of the contamination. A 50 tonne per hour, transportable thermal unit will be used to process the soil and redeposit it on-site. The unit has been successfully pilot tested on similarly contaminated soils at a 7 tonne per hour rate with a destruction effectiveness of approximately 98%. The soil is, after mechanical pretreatment, fed to a rotary kiln. The volatile matter is released from the soil at temperatures up to 600°C and released gases burnt at upto 1300°C. The plant is scheduled to begin operation early in 1988. In addition, experiments to evaluate ennanced indigenous microbial degradation have been carried out. Although not completed at the time of writing, the initial results were not promising because of the difficulties of achieving contaminant/microbe contact. For contaminated water, a combination of air stripping, flocculation, sedimentation and filtration are under consideration.

3.5 Pintsch-uil Site, West Berlin, FRG

The Pintsch-uil Site (9) is located in an industrial estate of West Berlin. The recovery of used oils has been carried out since 1924. Residual products were left in several pits and subsequently seeped into the soil and groundwater. After an initial inspection in 1976, the water authorities in charge directed that groundwater samples be taken. Considerable groundwater pollution was detected and resulted in a requirement for groundwater clean-up. After thorough investigation of

the site, three extraction wells with a maximum capacity of 40 m^3/h at 25 m WC were constructed.

A preliminary pollutant analyses of groundwater samples indicated extensive contamination with a wide variety of organic compounds. Results showed concentration for:

hydrocarbons	up to	16,000 mg/l
oils	up to	1,000 mg/l
phenols	up to	225 mg/l

In addition to the dissolved and undissolved oils and their compounds, groundwater contamination is primarily caused by volatile organic compounds (VOCs), and chlorinated hydrocarbons.

A pilot plant with a capacity of 40 m^3/h was designed and constructed to purity ground and seeping water. It comprised an oil separator, flotation, countercurrent desorption with exhaust purification and active carbon purification.

The other major part of this remedial activity comprised a full-scale cleaning of contaminated soils using a high-energy water based stripping process.

3.6 Province of Zuid-Holland, Netherlands

The contaminated soil at the former gasworks site in the Province of Zuid-Holland, has been excavated and transported to the thermal destruction installation of Ecotechniek (10). The soil is contaminated primarily with polynuclear aromatics (PNA's) and complexed cyanides (ferri-ferro cyanides) caused by spillages and dumping of waste materials. The installation consists primarily of an internally heated rotating kiln (direct heat transfer) and an after-burner for the off gases; these operate at a maximum temperature level of 550°C and 1100°C respectively.

Main purposes of the demonstration project are:

i) Evaluation of the treatment results and environmental aspects of the thermal cleaning of soil from a former gasworks site.

ii) The development of a standard evaluation methodology for soil treatment plants in general. The evaluation was carried out using the methodology developed by TNO (11). The evaluation was carried out over several two day periods to include:

   a) 'easy to clean', sandy soil chiefly contaminated with polynuclear aromatic hydrocarbons (PAH's) from a gasworks site; and

   b) 'difficult to clean', clayey soil containing rubble and contaminated with PAH's and mineral oil.

A carefully designed statistical sampling programme (10) was applied to both input and output soils. Gaseous emissions from the plant were also monitored. While removal rates above 95% were achieved for both soils the 'difficult soil' did not fully meet the statistically based requirement in respect to all parameters. However, it was suggested (11) that some modification of the 'standard' sampling and evaluation method might be necessary. All air emission standards were met.

3.7 Asten Site, Netherlands

The Asten Site in the province of Noord Brabant is a petrol/(gasoline) station, where the soil is contaminated with petrol containing small amounts of lead, and a small quantity of diesel oil (12). The contamination was caused by a leaking tank. At least 30,000 litres of normal gasoline have leaked and about 1500 cubic metres of soil have been contaminated. A 150 mm layer of free product was found in wells; 20,000

litres have been recovered by pumping. The soil is generally sandy and the water table at about 2.5 m below the surface. Concentrations in the soil vary mainly between 1000 and 5000 mg/kg gasoline.

This project is aimed at optimizing the treatment of deeper layers of contaminated soil by enhancing in situ microbial activity. The development of in situ techniques is important for the reclamation of other similar sites. It is expected that the use of this technique will result in cost reduction since it will avoid costs for excavation and allow the petrol station to continue its operation.

A series of laboratory experiments have been carried out to determine the optimum treatment conditions for the soil both in terms of microbial degradation and infiltration of liquid/leaching of the soil including tests using 200 mm diameter undisturbed soil columns taken from the site. A design for the clean-up operation has been produced based on these laboratory studies.

3.8 Wijster, Netherlands

The Wijster site, in the province of Drenthe was formerly occupied by a waste disposal company. The primary emphasis in the project is an improvement of landfarming methods for the bio-destruction of gas oil, crude oil and halogenated hydrocarbons (for example, hexachlorocyclohexane).

Contaminated soil will be excavated and spread over a drained sand bed. The sand bed will be isolated from the sub soils by a plastic membrane. Nutrients will be added and the contaminated soils will be added and the contaminated soils will be covered by an oxygen permeable plastic membrane or plants to prevent erosion.

3.9 Peak Oil, Tampa Florida, USA

The Peak Oil Site was previously operated by an oil-refiner (13). Investigations started in 1984, showed that a waste lagoon contaminated with oil re-fining waste containing PCB's and lead (and also acetic acid) was contaminating the groundwater. The soil in the area is sandy and the groundwater table very near to the surface. The lagoon was drained of water, and the contents then mixed with sand, soil and lime to further adsorb water and to neutralize the acidic waste. The PCB's and lead contents of the treated waste were determined as less than 50 mg/kg and 10-15 mg/kg respectively. Thermal destruction technology was selected for the clean-up of the waste lagoon.

The material then moves through the furnace where it is exposed to infrared radiation in multiple temperature-controlled zones. Zone temperatures are controlled by varying the input power (electric) to maintain preset zone setpoint temperatures. As the material moves through the furnace on the belt, it is exposed to the thermal environment necessary for oxidation of volatiles and solid organics.

The field phase of this project has been completed successfully and a report is being prepared (December 1987) by the U. S. Environmental Protection Agency. The trial was successful, although some difficulties were encountered with the exhaust gas treatment system.

As noted above, the lagoon material contained lead, so that the treated soil/ash produced by the plant remains contaminated with lead. A final disposal route for the material has yet to be selected.

3.10 Eglin Air Force Base, USA

This jet fuel spill site is near the city of Fort Walton Beach in Florida (14). In 1984, a large area of dead grass appeared in the base

petroleum storage area. The smell of fuel indicated that an underground fuel leak had occurred. Pressure testing of underground fuel lines revealed the source of the spill, a one litre per minute leak in a 150 mm diameter pipeline. The duration of the leak is unknown; however, soil and groundwater sampling indicates that as much as 100,000 litres of jet fuel have contaminated 6000-8000 cubic metres of soil and shallow groundwater.

The goals of this site demonstration are (14) to generate new data on the in-situ degradation of specific jet fuel components, to optimize nutrient/oxygen additions, and to maximize contact between nutrients, soil microbes and fuel soaked soils. A variety of infiltration methods are being evaluated. The study will be conducted over a two year period to provide information on the lower limits of biological removal of fuel compounds. A control area has been established in a fuel contaminated area on the upgradient end of the site. The purpose of this control area will be to compare natural levels of degradation to the enhancement provided by nutrient/oxygen additions.

3.11 Verona Well Field Site, USA

The Verona Well Field site consists of several distinct contaminated areas within about 40 hectares (15, 16). The well field itself contains 30 production wells that supply the entire city of Battle Creek, Michigan, including several major businesses. The site also includes a railroad marshalling yard and two solvent facilities. The Thomas Solvent Raymond Road (TSRR) facility is a former solvent repackaging and distribution facility. Solvents were stored in 21 underground storage tanks which were later discovered to be leaking. The TSRR facility is located about one mile upgradient of the well field. It is primarily a residential area surrounded by a few businesses.

Chlorinated hydrocarbons are the most significant environmental contaminants. Groundwater and soil contamination within the TSRR facility was found with VOCs as high as 100 mg/l and 1,000 mg/kg respectively. The total estimated mass of organics in groundwater and soil at TSRR was 200 kg and 770 kg respectively. The total contaminated area is about 900 m^2. The remedial action selected for the site comprises a groundwater extraction system (GWE) in conjunction with a soil vapour extraction (SVE) system. It was estimated that groundwater contamination could be reduced to 100 ppb in 3 years and the total contaminant mass reduced by 98% in 1 1/2 years.

The key components of the SVE system are extraction wells screened primarily in the unsaturated zone and a vapour phase activated carbon treatment vessel. A performance goal of 10 mg/kg total VOCs in the unsaturated zone was established. It is expected that this will be achieved in about 2 years.

Initial results indicate well influence of about 16 m radius, that recovery rates may be higher than estimated but that the total amount of contaminants probably exceeds the estimate of 770 kg. A statistically based programme of soil sampling has been established to assess overall performance and the progress of the removal operation.

3.12 Asahi Electrochemical Co. Site, Japan

This site, located in Arakawa-ku, Tokyo, was used from 1917 primarily for the production of sodium hydroxide and bleaching powder, but also to produce soap, margarine, hydrogen chloride and chlorinated organic compounds. During the period 1955 to 1966 the company operated the mercury-electrolysis method to produce high quality sodium hydroxide.

The plant was closed in 1979 as part of a plan to relocate industry away from residential areas. The site was scheduled for re-use for a college, public park, municipal wastewater treatment plant, and community complex. During factory demolition in 1978, soils containing up to 15.6% (3.68% mean) mercury were found beneath the electrolysis vessel. About 840 m^3 of these heavily contaminated soils were drummed and taken to an off-site mercury roasting plant about 1000 km away to recover mercury in 1979-80. About 54,000 m^3 soils contaminated with mercury above 2 mg/kg were contained in an on-site pit after immobilization of soils with more than 10 mg/kg mercury (32,000 m^3) with sodium sulphide. The sides of the pit were lined with a concrete barrier wall. The base was formed by low-permeability natural strata. The pit was capped with EPDM sheets 1.5 mm thick and covered with 1.2 m of soil. Methane generation by organic matter in the buried soil required installation of gas extraction and monitoring wells.

4. EMERGING THEMES

A number of the projects involve microbial treatment either of groundwater or of soil. In some cases, the intention is to achieve treatment in-situ, in others, the treatment is achieved after extraction/excavation. It was generally agreed during the discussions at the Washington DC meeting, that microbial treatment of many contaminants is a proven possibility under the right conditions, but that the major limiting factor to practical application is the difficulty of ensuring contact between bacteria and contaminants, both in terms of getting the treatment agents to penetrate the soil and of getting the contaminants into solution, and thus available to the bacteria. The practical tests of application methods (Elgin A F Base) and thorough laboratory trials prior to field application (Asten petrol station) are thus important complements to the field demonstrations of microbial treatment, as are the basic studies and the concentrations to be dealt with.

5. CONCLUSIONS

The Pilot Study has started well, and there has already been a fruitful exchange of information and views between the participants. This exchange is based on the active co-operation and participation of government officials, academics, industrialists and researchers drawn from the participating countries. It is to be hoped that further countries will recognize the benefit of such international co-operation and associate themselves with the study, either as full participants contributing demonstration projects themselves or in an observer role. Enquiries about the Study should be addressed to the Pilot Study Director (D. E. Sanning) or to the national contacts listed in Table 2.

6. AKNOWLEDGEMENTS

Space does not permit the listing of all those contributing to the Pilot Study, but the Pilot Study Director would like to give particular thanks to the representatives of the Co-pilot countries, K. Stief for the FRG and Ms. E. Soczo for the Netherlands, and to those reporting on the individual projects (see References).

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TABLE 1

Country	Project	Technologies, etc.
Canada	Ville Mercier	Groundwater treatment.
Denmark	Skrydstrup	Groundwater and soils clean-up, microbial techniques.
FRG	Charlotenberg, Berlin	Soils clean-up (high pressure water washing).
FRG	Unna-Boenen, Coke oven plant	Soils clean-up by thermal treatment, microbial treatments.
FRG	Pintsch-uil, Berlin	Groundwater treatment, soils clean-up by high-energy water stripping process.
the Netherlands	Rotterdam	Thermal treatment of soils.
	Asten	In-situ and post extraction clean-up of groundwater (and associated soils) by microbial techniques.
	Wijster	Microbial land farming.
USA	Peak Oil	Thermal treatment of soil.
	Eglin Air Force Base	Groundwater/soils clean-up by in-situ microbial treatment.
	Verona Well Field	Soils/groundwater clean-up by soil vapour extraction.
Japan	Asahi Electrochemical Co.	Soils treatment by thermal and chemical means.

TABLE 2: National Contacts

Canada*	Mr. J. Schmidt	Environment Canada Burlington, Ontario.
Denmark*	Dr. S. Vedby	National Agency of Environmental Protection, Copenhagen.
FRG*	Mr. K. Stief	Unweltbundesamt, Berlin.
France	Mr. R. Goubier	ANRED-France, Angers.
Greece	No official contact	
Italy	No official contact	
Japan*	Mr. T. Ikeguchi	Institute of Public Health, Tokyo.
Netherlands*	Ms. E. Soczo	RIVM, Bilthoven.
Norway	Mr. M. Helle	State Pollution Control Authorito, Oslo.
Spain	No official contact	
United Kingdom	Mr. J. Mather**	British Geological Survey, Wallingford.
USA*	Mr. D. E. Sanning	U. S. Environmental Protection Agency, Cincinnati, Ohio.

*Active Participant
**Contact for information, not official government representative.

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